METHOD AND SYSTEM FOR PATIENT SPECIFIC PLANNING OF CARDIAC THERAPIES ON PREOPERATIVE CLINICAL DATA AND MEDICAL IMAGES

[0001] This application claims the benefit of U.S. Provisional Application No. 61/592,113, filed Jan. 30, 2012, U.S. Provisional Application No. 61/651,052, filed May 24, 2012, and U.S. Provisional Application No. 61/704,726, filed Sep. 24, 2012, the disclosures of which are herein incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to patient-specific simulations for planning cardiac resynchronization therapy, and more particularly, to simulations using multi-scale computational models of heart ventricles personalized from preoperative clinical data and medical images to predict outcomes of cardiac resynchronization therapy for a patient.

[0003] Patients with heart failure often present dysynchronous ventricular contraction. For example, the left ventricle (LV) and right ventricle (RV) do not beat synchronously, which decreases the efficiency of the cardiac pump. Cardiac Resynchronization Therapy (CRT) treats this condition by artificially pacing the cardiac muscle through an advanced pacemaker with several pacing leads. In order to implement CRT in a patient, a pulse generator (pacemaker) and multiple leads, including a left ventricle lead, a right ventricle lead, and a right atrial lead, are used to synchronize ventricle contraction in a patient. Although CRT is typically an efficient treatment of heart failure, thirty percent of patients do not respond to the therapy even though they are within the recommended guidelines for CRT. In such cases, the patient's heart does not improve as a result of the CRT and the ejection fraction, which is a measure of cardiac efficiency, stays constant despite the therapy.

BRIEF SUMMARY OF THE INVENTION

[0004] The present inventors have determined that a predictive framework is desirable to select patients that will respond to Cardiac Resynchronization Therapy (CRT), and to optimize lead placement and programming to increase the number of suitable patients. The present invention provides a method and system for patient-specific CRT planning based on preoperative medical image data, such as magnetic resonance imaging (MRI) or Ultrasound data. Embodiments of the present invention provide an integrated system based on multi-scale computational models of heart ventricles personalized from preoperative patient data and medical image data to provide metrics that quantify the acute outcomes of CRT in a patient, such as heart dynamics, ventricular volume, cardiac synchrony, and pressure curves.

[0005] In one embodiment of the present invention, a patient-specific anatomical model of left and right ventricles is generated from medical image data of a patient. A patient-specific computational heart model is generated based on the patient-specific anatomical model of the left and right ventricles. CRT is simulated at one or more anatomical locations using the patient-specific computational heart model.

[0006] These and other advantages of the invention will be apparent to those of ordinary skill in the art by reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** illustrates a method for patient-specific CRT planning according to an embodiment of the present invention;

[0008] FIG. **2** illustrates an overview of a framework for implementing the method of FIG. **1** according to an embodiment of the present invention;

[0009] FIG. **3** illustrates a detailed framework of the computational heart model component to describe the multiphysics interactions considered in the computational heart model according to an embodiment of the present invention;

[0010] FIG. **4** illustrates a method for generating the patient-specific anatomical model according to an embodiment of the present invention;

[0011] FIG. **5** illustrates fusion of LV and RV surface models;

[0012] FIG. **6** illustrates exemplary results for calculating a computational model of fiber orientation;

[0013] FIG. **7** illustrates the electrophysiological conduction system of the heart;

[0014] FIG. **8** illustrates a sliding model of cell contraction;

[0015] FIG. **9** illustrates variation of the active contraction stress with respect to the electrical command signal;

[0016] FIG. **10** illustrates a Rheological model of cardiac biomechanics;

[0017] FIG. **11** illustrates the four cardiac phases;

[0018] FIG. **12** illustrates a circuit analogy of a 3-element Windkessel model;

[0019] FIG. **13** illustrates improvements obtained using the prediction/correction model of isovolumetric phases according to an embodiment of the present invention;

[0020] FIG. **14** illustrates modeling the effect of arteries and atria on the ventricular motion using a base stiffness parameter;

[0021] FIG. **15** illustrates generating a pericardium model according to an embodiment of the present invention;

[0022] FIG. **16** illustrates an algorithm for determining patient-specific parameters of the computational heart model according to an embodiment of the present invention;

[0023] FIG. **17** is a block diagram illustrating the framework for simulating the heart function using the computational heart model according to an embodiment of the present invention;

[0024] FIGS. **18-25** illustrate exemplary results of patient-specific heart simulation; and

[0025] FIG. **26** is a high-level block diagram of a computer capable of implementing the present invention.

DETAILED DESCRIPTION

[0026] The present invention relates to patient-specific Cardiac therapy planning based on preoperative clinical data and medical images, such as ECG, MRI and/or Ultrasound data. In an advantageous embodiment, the present invention is illustrated on the specific case of cardiac resynchronization therapy (CRT). Embodiments of the present invention are described herein to give a visual understanding of the patient-specific CRT simulation methods. A digital image is often composed of digital representations of one or more objects (or shapes). The digital representation of an object is often described herein in terms of identifying and manipulating the objects. Such manipulations are virtual manipulations accomplished in the memory or other circuitry/